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CONCERNING THE HORIZONTAL VELOCITIES OF METAL DURING DRAWING

\- USSR -

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[Following is a translation of an article by I. K. Suvorov in the Russian-language periodical *Izvestiya Vysshikh Uchebnykh Zavedeniy, Chernaya Metallurgiya* (News of the Higher Educational Institutions, Ferrous Metallurgy), Moscow, No 5, May 1960, Pages 68-71

At the present time, not all elements of the drawing process have yet been sufficiently fully studied. There is still not a single opinion on the problem of the longitudinal velocities of a metal during deformation in a drawing hole. Some studies [1, 2, and others] consider that the longitudinal velocities of different layers of a metal are not identical along the cross-section: the internal layers lag behind the external. Such a suggestion arose on the basis of an analysis of the characteristic distortion of the cross-section of the rear end of the bar during its drawing and also changes in the system of coordinates drawn before deformation on the external surface of specially prepared models, each composed of two parts. As is known, ends of the bar cut smoothly before drawing turn out to be pitted; holes of a conical form appear in them. In the opinion of a number of researchers, the formation of these holes is explained by the presence of variations in the longitudinal velocity of the metal along the cross-section of the bar during its deformation in the drawing hole.

Other researchers, including I. M. Pavlov [3], believe that the longitudinal velocities along the cross-section of the metallic bar are equal during its deformation by drawing. This follows from the fact that the established process of drawing proceeds under conditions characterized by the presence of ingoing and outgoing ends of the bar, the action of which, as I. M. Pavlov demonstrates, is manifested in the equalization of longitudinal velocities, for at a very close distance from the surface of entry of the metal in the area of deformation and the outgoing surface of the end of the bar, there is a rigid body in terms of the possibility of displacing different layers or particles of metal under pressure acting in the zone of deformation.

Thus, there are various views on the very important question of the theory of drawing. Moreover, this problem is of definite interest both from the theoretical, as well as the practical, point of view since the character of the state of tension of the zone of deformation and, in consequence, even the power conditions of drawing depend on the velocity conditions along the cross-section of the deformed bar, together with the effect of other factors.

Existing diversity of opinion can be explained principally by the insignificant amount of suitable experimental data.

Special experiments were set up to introduce possible clarity into the disputed state of drawing theory.

The problem was studied by the method of the "precise shear" proposed by I. M. Pavlov [3]. The method specifies the observation of the changes of a perfectly flat cross shear of the rear end of a bar in the drawing process. Recording the changes, one can evaluate the longitudinal velocities of different layers of the cross section of the bar.

In order to carry out the experiment, models 250mm in length and 12 mm in diameter were prepared from brass bars. In this connection, special attention was given to the precision of the cross shear of the rear end. The front end was tapered. The models were annealed in order to relieve the cold hardening and pickled to remove the scale. This assured obtaining a more homogeneous structure along the cross-section and constancy in the properties of the surface of the bars.

Drawing was performed in a 10-ton tensile testing machine through a draw plate made of the alloy VK-6 with an operating cone angle of $12^{\circ}\,40'$ and a diameter of the outgoing end of 10 mm.

Preliminary experiments showed that a conically-shaped hole appeared in the rear end of the bar after drawing. Thus, the data in hand from other studies was affirmed. However, this still did not provide the basis for affirming the presence of a variety of metal velocities across the cross-section of the bar. In order to reach such a conclusion, it is necessary to trace the continuous change of the flat shear of the ingoing end in the process of its deformation along the entire length.

Inasmuch as visual observations of distortion of the flat shear are quite difficult and do not allow its character to be recorded, it was decided to find the distortion on the flat shear of the bar drawn from the draw plate after stopping the drawing process at a given moment.

It is characteristic that the distortion of the flat shear of the rear end of the bar is not observable, according to preliminary data, prior to its coincidence with the ingoing surface of the metal into the draw hole. Therefore, basic attention was devoted to studying the character of the change of the flat shear indirectly in the zone of deformation, the drawing of which constituted about 9 mm.

One may assume that observation of the character of the flat shear at 9 - 10 points consecutively along the length of the zone of deformation assures the reliability of judging the phenomenon under study. Therefore, the model was drawn from the draw plate through each 0.9 to 1 mm of length of the rear end along the length of the zone of deformation, which was determined by the customary indicator in the process of drawing. Thus, it proved possible to record the condition of the ingoing end at 9 - 10 points along the zone of deformation and to establish the character of the change of its flat shear in the process of deformation in the draw plate.

After drawing the model from the draw plate, it was washed in benzine and carefully rubbed, then before each subsequent experiment, the draw holes were covered with a thin layer of machine oil. Thus, the constancy of the condition of the surface of the draw plate were guaranteed and consequently, also the constancy of the friction conditions of the metal on the wall of the instrument. An attempt to carry out drawing without the use of oil failed since the front end broke away.

The deformed model was planed off to a depth of half the diameter which made it possible not only to observe the character of the change of the precise shear, but also to measure exactly the depth of the holes which were formed. The diameter of the bar along the shear and the depth of the hole were measured in an instrument microscope with a magnifying power of 30. The results of measuring are presented below:

D, mm	11.53	11.27	11.15	11.07	11.76	10.62	10.46	10.25	10.00
ΔD, mm	0.45	0.71	0.83	0.91	1.22	1.36	1.52	1.73	1.98
f, mm	0.0	0.0	0.0	0.10	0.20	0.38	0.50	0.67	0.89

(initial diameter of the bar $D_1 = 11.98$ mm; final diameter - 10 mm; D is the diameter of the cross-section of the area of deformation; f is the depth of the hole in this cross-section; $\Delta D = D_1 - D$).

The data of the experiment permitted the character of the distortion of the precise shear of the rear end of the bar to be traced in the process of its passing through the draw hole. The illustration shows this distortion, obtained in the form of a photographic mosaic of the change of the precise shear of the end as it passes along the area of deformation.

It is clear from the data presented that the distortion of the precise shear of the rear end of the bar takes place not during the approach and not even at the moment of its coincidence with the surface entering into the draw plate. Although the experiments were carried out under a comparatively high degree of compression (on the order of 30%), the flat shear of the end of the bar began to change deeply only in the zone of deformation (at the moment it passes approximately one half the area of deformation). Naturally, while distortion of the flat shear is absent, there is no foundation for accepting the presence of a variety of velocities along the cross-section. At the same time, the experiment shows that at a given moment of drawing one can actually observe the variety of velocities of different cross-sections of the bar. Such conditions are created when the aligning action of the volume of metal enclosed at the rear end is halted. This begins to appear after the shear of the rear end of the bar has passed a significant part of the area of deformation. Then distortion of the flat shear appears which increases with the progress of it along the remaining part of the area of deformation.

It is interesting that during forging the distortion of the precise shear of the rear end of the strip begins during its approach to the ingoing area of the metal into the rollers [4], and not after entering into the area of deformation as occurs during drawing when the distortion of the precise shear takes place directly in the draw plate.

Thus, if one ignores the presence of a sharply expressed variation in the velocity in an insignificantly small length of the bar -- in its rear end, observed in the terminal stage of the process, then one may assert that the drawing process takes place under conditions of constancy of the horizontal velocities along the cross-section.

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